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Modal Quantification Over Individuals

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My immediate concern in this paper is to define the semantics of the English modal auxiliaries *can* and *will* in their dynamic and quantificational uses, which are exemplified in the primary readings of 1 and 2, respectively.

1. Joan can/will sign anything. DYNAMIC
2. A basketball player can/will have good eyesight. QUANT.

The broader theoretical question that lies in the background of the analysis is whether or not the grammar allows for modal quantification over individuals. I answer this question affirmatively, on the basis of arguments given in Section 3 about the interpretation of *can* and *will*. In Section 3, I also make an argument concerning the generic operator proposed in Gerstner and Krifka (1987) which supports this affirmative conclusion. The latter argument is self-contained in that it shows the need for restricting an operator that binds individual variables by a full-fledged accessibility relation.

Section 1 is devoted to dynamic uses of *can* and *will*, specifically to data showing that they should be treated as dyadic predicates, of category IV/IV; semantically, they are two-place functions, combining with the individual correlate of a property expression to form a modal property expression. Section 2 is devoted to showing that quantificational *can* and *will* share the fundamental characteristics of adverbs of quantification. They are assigned to category S/(IV(x)). The semantic rules and the definition of accessibile individuals are given in Section 4. The rules for modals in category IV/IV differ from those for modals in category S/(IV(x)) only with respect to the subject position; both sorts of rule treat the modals as individual variable binders.

Section 1: Dynamic Modals

The first set of facts we will look at provides evidence that dynamic modals are predicates, similar to control verbs on Chierchia's (1984, 1985) account, in contrast to epistemic modals, which are S-operators. It is important throughout this section that *can* and *will* in example sentences be read in their dynamic senses, which can be glossed as 'be capable of' and 'be willing to', respectively.

Using substitution of extensionally equivalent NPs as a test for opacity, we find that the subject position in sentences with dynamic modals is referentially transparent, while with epistemic modals it is opaque. Consider the (in)validity of the inferences in 3 and 4.

DYNAMIC
3a. The best track and field competitor can run a 4 minute mile.
b. Joan is the best track and field competitor.
---
c. Joan can run a four minute mile.

EPISTEMIC
4a. The best track and field competitor may run a 4 minute mile.

b. Joan is the best track and field competitor.
-----/--------
c. Joan may run a 4 minute mile.

When the modals in 3 are read dynamically, the inference is valid; when the modals in 4 are read epsitemically (or deontically), on the other hand, there is a de dicto reading of the subject in a that makes the inference invalid.

The lack of a de dicto reading of the subject NP with dynamic modals manifests itself again in the scope possibilities for subject quantifiers. Subject quantifiers are ambiguous in scope with respect to epistemic modals but always take wide scope with respect to dynamic modals. The fact that dynamic 5, but not epistemic 6, is a contradiction is an example of the effects this has.

\# 5. Every radio can get Chicago stations and no radio can get Chicago stations.
6. Every radio may get Chicago stations and no radio may get Chicago stations.

The subject quantifier can take scope under another operator just in case that operator has sentential scope. The fact that subject quantifiers never take scope under dynamic modals and the fact that the subject position in dynamic modal sentences is referentially transparent are evidence that these modals don't have sentential scope. The obvious alternative is that they have scope over the VP, and this is the position that I will adopt.

Two additional pieces of evidence suggest that dynamic modals are not only operators on VPs but that they are actually predicates and not functors. First, in contrast to epistemic modals, dynamic modals impose selectional restrictions on the subject and on the VP. Both dynamic can and dynamic will select for non-stative VPs, as can be seen in the paradigm 7-10.

7. Joan can/will climb this tree.
*8. Joan can/will be five feet tall.
9. Joan can/will be long-winded.
[note: Joan is being long-winded.]
*10. Joan can/will be drunk/in a coma.

The contrast between 9 and 10 is significant because it shows that the selection is for non-stative rather than stage-level (in the sense of Carlson 1977) predicates, grammaticality with progressive aspect in English signalling that a predicate can be interpreted as a non-stative.

Dynamic will also imposes selectional restrictions on its subject, combining with inanimate subjects only to the extent that we are willing to attribute some agentive powers to them. 11-14 show effects of this selection.

11. Joan will sit next to anyone.
*12. This box will sit next to anyone.

13. The car won't start.
*14. The parasession won't start. (*dynamic)

A negative empirical observation is difficult to illustrate, but I have found no evidence suggesting that epistemic modals impose selectional restrictions. They seem to combine freely with any sort of subject (+/- animate, +/-concrete, referential or not, e.g.) and with any sort of VP (stative, non-stative, stage-level, individual-level, e.g..)

We expect predicates to impose selectional restrictions on their arguments, but not on the sub-constituents of their arguments. Dynamic can and will restrict the VP and the subject NP because they take VP and NP, not S, as arguments.

Given that the dynamic modals take the VP as an argument, we want to know whether they are predicate modifiers (like VP adverbs) or are predicates themselves (like control verbs). If they are predicate modifiers, then in the simple case they are of type <<e,t>,<e,t>>. The semi-modals be able to, be capable of and be willing to, which have semantics intuitively similar to the dynamic modals, would perhaps be of a similarly high type. But then we would have to say that these expressions are systematically ambiguous in type since we can iterate them, forming sentences such as those in 15 and 16.

15. Joan is willing to be willing to quit smoking.
16. Joan is capable of being able to run six miles a day.

Noticeably, the epistemic semi-modal have to (=must) cannot iterate (18). There is no semi-modal counterpart of epistemic may; 19, with the epistemic control predicate is included to complete the paradigm.

*18. She has to has to be the murderer.
*19. The gym instructor is almost sure to be almost sure to be a good tennis player.

Rather than incorporate this recursion of types into the semantics of the dynamic modals and their semi-modal paraphrases, we can instead abandon our initial hypothesis about their type. The second order system espoused in Chierchia (ibid.) gives us a way of handling predicates that take predicative arguments while maintaining a constrained type system. In Chierchia's system, propositional functions are systematically related to individuals (which are actions and states) by a nominalization function, the individual correlate of a predicate P being represented P. Predicates appearing in argument positions have undergone nominalization, one of their characteristics being that they lack inflection for tense. Taking the first argument of dynamic modals to be such a nominalized predicate, their type is the same as that of other transitive verbs: <e, <e,t>>. The lack of tense in the VP complement is consistent with this analysis. Following Chierchia, I will reserve single slash notation in category names for predicates and double slash notation for functors, giving us IV/IV for dynamic modals (= Chierchia's type for control verbs) and IV//IV for VP modifiers.

The second empirical point which leads to analysing dynamic modals as predicates is precisely that they do, in their semi-modal form, nominalize. One of the central observations in Chierchia (ibid.) is that predicates (verbs, adjectives, common nouns) nominalize while functors (prepositions, determiners, adverbs) do not. Again, the facts about dynamic modals are in contrast to those about epistemic modals. Compare 20-23 to 24-27.

20. Being able to climb trees is pleasant.
21. Joan expects to be able to climb trees.

22. Being willing to attend evening lectures is an asset.
23. Joan intends to be willing to attend evening lectures.

*24. Being almost sure to be the murderer is unpleasant.
*25. Joan expects to be almost sure to be the murderer.

*26. Having to be the murderer is a fault. (*epistemic)
*27. Joan expects to have to be the murderer. " "

On the account being developed here, the infinitives and gerunds in 20-23 denote the individual correlates of dynamic modals saturated on all but their first argument position. Epistemic modals lack equivalent nominalizations because they are not predicates.

We now have a hypothesis that correctly predicts the facts about missing de dicto readings of the subject NP, selectional restrictions, and nominalizations. The hypothesis boils down to a categorial distinction between dynamic and epistemic modals: dynamic modals are predicates and epistemic modals are sentence operators. The facts reviewed have led us to treat the dynamic modal in combination with a VP as a modal property expression. What are the semantics of such an expression? Are we to say for the sentence Joan can climb trees that Joan has the property of there being a world where she climbs trees? There is something strange about this leveling of worlds and individuals and I motivate a semantics that avoids it in what follows.

Section 2: Quantificational Can and Will

A certain sort of sentence, exemplified by 28 and 29 below, shows that modals can bind individual variables; we can think of the modals in these cases as intensional variants of adverbs of quantification (see Lewis (1975).) In this section, I present data indicating that the modals in this sort of sentence (i) bind individual variables, (ii) bind variables unselectively, and (iii) are subject to the Prohibition Against Vacuous Quantification postulated in Kratzer (1989). In the next section, I argue that these modals have to be analyzed as variable binders.

28. A basketball player can be short.
29. A basketball player will be agile.

The primary interpretations of 28 and 29 are very close to those of the similar sentences with appropriate adverbs of quantification given in 30 and 31, the important similarity being the existential interpretation of the indefinite subject in 28 and its universal interpretation in 29.

30. Sometimes, a basketball player is short.
31. A basketball player is always agile.

Assuming the theory of indefinites of Kamp (1981) and Heim (1982), in which an indefinite NP contributes a variable but no binder for it to the logical representation, we have a straightforward account of 28 and 29 if we assume can and will are able to bind individual variables. Using restricted quantification, 28' and 29' represent 28 and 29, respectively.

28'. $\exists_x$ [basketball player (x)][short (x)]
29'. $\forall_x$ [basketball player (x)][agile (x)]

Since the quantifier in these cases is modal, the quantification here has to (somehow) be intensional.

Alongside the instances of modal quantification over individuals, are instances of modal quantification over situations, such as those in 32 and 33, which are close in meaning to 34 and 35, respectively.

32. During a busy week, a datebook can be handy.
33. When it snows, Kennedy airport will be jammed.

34. Sometimes, during a busy week, a datebook is handy.
35. When it snows, Kennedy airport is always jammed.

Assuming with Kratzer (1989) that stage-level predicates contain an extra argument position filled by a situation variable, while individual-level predicates lack such a position, the linear representations of 32 and 33 appear in 32' and 33', respectively. (l is the situation variable.)

32'. $\exists_{<l>}$ [datebook (x) & during a busy week (l)][handy(x)(l)]

33'. $\forall_{<l>}$ [it snows (l)][kennedy airport jammed (l)]

You will notice that the modal quantifier in 32' is treated as unselelctive, binding both of the free variables in its scope. The 'donkey sentences' in 36 -38, where the quantifiers bind tuples of (proper) individual va.iables are a more familiar sort of evidence of unselectivity.

36. A strong spice in a fish stew can ruin it.
37. An introductory textbook about a difficult subject will only explain its basic principles.
38. A man who owns a donkey can/will beat it.
(relevant readings: some/all possible <man, donkey> pairs are s.t. the man beats the donkey.)

Unselectivity in variable binding is the second property modal quantifiers share with adverbs of quantification.

Thirdly, the modal quantifiers appear to respect Kratzer's (1989) Prohibition Against Vacuous Quantification, which requires that every quantifier bind at least one variable (and that this variable occur in both the restriction on the quantifier and in its scope.) NP quantifiers aren't in danger of violating the Prohibition, since they provide their own variables, but verbal quantifiers (whether adverbs or modals), which are syntactically independent of their arguments, can in principle occur in sentences where there are no variables. Given what we've said above, we know that both indefinite NPs and stage-level predicates introduce free variables into the logical representation. When an adverb of quantification occurs in a sentence without either sort of free variable, the result is ungrammatical, as can be seen in the paradigm (d)-(e).

(c) Sometimes, a soccer player is tall.
(d) Peter is sometimes unhappy.
*(e) Sometimes, Peter is tall.

The quantificational modals can and will are also subject to this constraint; the combination of can or will with a definite subject and an individual-level VP is grammatical only if (i) the modals are interpreted epistemically, or (ii) the predicates are forced into a stage-level interpretation. This is illustrated in 39-41.

39. A basketball player can/ will be short.
40. Patrick Ewing can/will be intimidating.
*41. Patrick Ewing can/will be short.

The ungrammaticality of 41 on any but an epistemic (or a remote deontic) reading follows straightforwardly from what has been said so far: Kratzer's Prohibition rules out a quantificational reading (*no variable), and selectional restrictions rule out a dynamic reading (*stative predicate). The more general observation these hypotheses explain is that dynamic and quantificational modals, given definite subjects, always disambiguate predicates in favor of stage-level readings, whereas epistemic and deontic modals do not.

This section has given us reason to suppose that can and will are variable binders, sharing the basic characteristics of adverbs of quantification. The next supports this supposition by working out

what the semantics would be like if these modals weren't variable binders.

Section 3: Arguments for Modal Variable Binding

Consider again sentence 28 on its primary reading, where intuitively it means something like 'It's possible for an individual to be short and still be a basketball player.' Suppose that no modals bind individual variables; specifically, suppose the modal can in 28 does not bind the individual variable x in subject position. Then something else has to bind x.

28. A basketball player can be short.
    POSS [basketball player(x)][short (x)]
29. A basketball player will be agile.
    NEC [basketball player(x)][agile (x)]

I'll assume for the sake of argument that we can choose between an implicit existential operator and an implicit universal (or generic) operator to bind x. Regardless of which we choose, the modal has to take wide scope over the implicit variable binder, or we get the wrong readings (regardless of the accessibility relation.) The sentence means neither 'There is a basketball player x such that there is an accessible world where x is short' nor 'Basketball players x generally are such that there is an accessible world where x is short'. For the sentence does not mean that there is a possibility for any particular basketball player(s) to be short. (For the time being, I am disregarding the modality of the generic operator. This is for simplicity; it doesn't affect the point at hand.)

If the implicit operator is existential and has scope under POSS, we get the representation in 28!; if it is a narrow scope universal, we get the representation in 29!!.

28!. POSS [$\exists_x$ [basketball player(x)][short(x)]]
28!!.POSS [$\forall_x$ [basketball player(x)][short(x)]]

With an appropriate accessibility relation, one of these representations might suffice to get the truth conditions of 28 right, but it will be constructive to consider what such an accessibility relation would have to be and what the consequences of the analysis would be for the semantics.

The truth conditions of 28! will be something like this: there is an accessible world where some individual is in the intersection of basketball player and short. This accessibility relation cannot be construed as epistemic since it can be true in a situation where it is known that all basketball players are tall. The same considerations would block treating the accessibility relation as 'stereo-typical', determined by what is typically the case for the relevant individuals in the actual world.

To make a representation like 28! (or 28!!) work, we could key the accessibility relation to the common noun basketball player, making accessible only those worlds w' where individuals in the extension of basketball player at w' have what we deem to be the essential characteristics of basketball players. 28, then, would mean that being short is compatible with the essential properties of basketball players, which is basically the right reading.

Notice first of all, however, that the difference between 28! and 28!! has lost all of its intuitive content on this account. We have to choose between (a) and (b):

(a) 28 is true iff there is a world w' where basketball players have

all the essential properties of basketball players s.t. there is a short basketball player is true at w'.

(b) 28 is true iff there is a world w' where basketball players have all the essential properties of basketball players s.t. all basketball players are short is true in w'.

Although intuition doesn't readily make the choice (which is interesting in and of itself), we would have to choose (a) over (b) because the models in which (b) is true are only a subset of those in which (a) is true. This means that in making the assumption that modals cannot bind individual variables we are forced to also assume that there is double existential quantification going on in 28 (the modal quantifying over worlds is existential and the implicit operator binding x is existential) and this doubling, via an implicit operator, should make us suspicious. The implicit quantifier seems superfluous: its only reason for being is to satisfy the stipulation that the modal cannot bind individual variables. If, on the other hand, the modal can quantify over possible individuals, we can do without the implicit existential quantifier, and represent 28 as we did at the outset of Section 2, with 28'.

28'. $\exists_x$[basketball player (x)][short (x)]

Another consideration speaks even more forcefully in favor of letting the modals in 28 and 29 bind individual variables. Consider 29, where the modal is universal, on the supposition that it doesn't bind the individual variable in subject position. As with 28, the only viable representations are where the modal has wide scope over some sort of implicit operator which binds the individual variable. Strikingly, we are forced to choose a narrow scope universal (or generic) operator (giving us the truth conditions in (a)) over a narrow scope existential operator (which would have the truth conditions in (b)) as the implicit binder for x. This is remarkable becuase the modal in this case is also universal.

(a) 29 is true iff in all worlds w'where basketball players have the essential properties of basketball players, All basketball players are agile is true in w'.

(b) 29 is true iff in all worlds w' where basketball players have the essential properties of basketball players, There is a basketball player x s.t. x is agile is true in w'.

(b) would represent a sentence something like: It is necessarilly the case if basketball players have what we deem to be their essential properties that there is a basketball player who is agile, which certainly isn't available as a reading of 29. (a) gives the right truth conditions for 29, but together with the proposed truth conditions for 28, it confronts us with a discomforting coincidence: when the modal is existential, the purported implicit operator is also existential; when the modal is universal, the implicit operator is universal. This co-variance in quantificational force is no coincidence at all if it is the modal itself which is binding the individual variable.

The third argument in favor of modal quantification over individuals concerns not the modals can and will, but the generic operator, G, proposed in Gerstner and Krifka (1987). The point of

this argument is that the generic operator has to be restricted by an accessibility relation (and not just the CN attached to its argument(s)) when it takes scope over a modal. The example I'll use to make the argument is 42, on its deontic interpretation.

42. A citizen may conduct arrests.

42 has a generic interpretation. On its deontic reading, it means, roughly: the average citizen is allowed to conduct arrests. Here, the existential force associated with the modal may is not affecting the interpretation of the indefinite; we have to assume that the variable gets bound by a non-overt generic operator, G. We also have to assume, because intuitively we want truth conditions something like (a) rather than (b), that G has scope over the modal.[1]

(a). 42 is true iff the average citizen x is such that there is a deontically accessible world w' such that x conducts arrests is true at w'.

(b). 42 is true iff there is a deontically accessible world w' such that the average citizen conducts arrests is true in w'

The third point to be noted in this discussion is that the generic operator is itself a generic operator, on Gerstner and Krifka's treatment and on mine. The strongest sign of its modality is that unlike NP determiners it lacks monotonicity properties. This lack of monotonicity properties is shared with modals, on Lewis' (1973) treatment of conditional modal sentences (in particular, his treatment of the problem of stengthening the antecedent of such sentences.)

The fourth point is a simple one: the generic operator is a restricted quantifier, minimally restricted by the CN of the argument it binds. This gives us a the representation in 42', where the quantification is over past and future, actual and potential citizens, not just citizens that exist in the here and now.

42'. Gx (citizen(x)) MAY (x conduct arrests)

The final, and major, point of this argument is that the kind of accessibility relation restricting the range of a modal must also restrict the range of the generic operator when it has scope over the modal. Take 42 as an example. Giving an imprecise but roughly standard analysis to the modal, and assuming for the sake of argument that the generic operator is restricted only by the CN citizen, 42 ought to mean: It is generally true of individuals x which are in the extension of citizen at some world that there is a world w' in the set of worlds deontically accessible from w such that x conducts arrests is true in w'. More briefly, anything in the domain of discourse that is a citizen has the property of conducting arrests in some deontically accessible world. This is a problem.

Suppose a world w' is deontically accessible to w just in case everything required by Massachusetts law in w holds in w'. It is a simple matter to construct models where the vast majority of individuals who are citizens are citizens in worlds where Massachusetts laws do not hold. In such a model, 42 can be false when we want it to be true, since it need not be true for citizens in these other worlds that they may conduct arrests. To solve this problem, we have to restrict the generic operator to deontically accessible worlds. Then 42 will be interpreted roughly as follows, which is

roughly correct: It is generally true for individuals x such that x is in the extension of citizen at a world w' deontically accessible from w that there is a world w'' deontically accessible from w such that x conducts arrests is true in w''.[2]

The last argument shows that there is at least one operator binding individual variables which is restricted by a full accessibility relation. This gives an idea of what an accessible individual is, and in the section that follows I give a definition of accessible at some w' in an attempt to formalize this. The preceding arguments led to the conclusion that can and will, in their quantificational uses, are modal variable binders, and I use the notion of accessible individuals in their semantic rules (also following.) Since we have seen that dynamic can and will combined with their first argument, are modal property expressions, and since, given their selectional restrictions, there will always be a variable 1 for them to bind, I have made the jump of treating them as variable binders as well. Typically, the accessibility relation restricting dynamic can will be stated in terms of things like the subject's physical, emotional, or intellectual characteristics; the typical accessibility relation restricting dynamic will will be stated in terms of things like the subject's habits, codes or quirks. The semantics given here incorporate this focus on the individual.

Section 4: Definitions and Semantic Rules

Given: An accessibility function is a function formed by composing a series of open sentences with n possibly distinct variables. An accessibility relation for a modal in category IV/IV or category S/(IV(x)) is such a function.

a. $j : w \longrightarrow f^{w}$, for all $w \in \{W\}$ (intension of an accessibility function)

b. For any world $w \in \{W\}$, f_n^w: $\langle d_1,\ldots,d_n \rangle \longrightarrow \{0,1\}$ (extension of accessibility function)

c. definition: For all $w' \in \{W\}$, an n-tuple of individuals $\langle d_1,\ldots,d_n\rangle$ is accessible at w' iff $f_n^{w'}(d_1,\ldots,d_n) = 1$.

d. definition: An n-tuple of individuals $\langle d_1,\ldots,d_n\rangle$ is accessible iff there is a world w' and a function $f_n^{w'}$ such that $f_n^{w'}(d_1,\ldots,d_n) = 1$.

Semantic Rules: P_n is a predicate saturated on all but n argument positions.

1. Dynamic can

$[CAN(\hat{}\, P_{n-1})(x)]^{w,g} = 1$ iff there is an n-tuple of individuals $\langle d_1,\ldots,d_n\rangle$ accessible at some w' such that $[P_{n-1}(x)]^{w',g'} = 1$, where $g'(x_1,\ldots,x_n) = \langle d_1,\ldots,d_n\rangle$ and $g'(x_n) = g(x_n)$.

2. Quantificational can

$[CAN(P_{n-1}(x))]^{w,g} = 1$ iff there is an n-tuple of individuals $\langle d_1,\ldots,d_n\rangle$ accessible at some w' such that $[P_{n-1}(x)]^{w',g'} = 1$, where $g'(x_1,\ldots,x_n) = \langle d_1,\ldots,d_n\rangle$.

3. Dynamic will

$[WILL(\widehat{\ } P_{n-1})(x)]^{w,g} = 1$ iff for all n-tuples of individuals $\langle d_1,\ldots,d_n\rangle$ accessible at some w' $[P_{n-1}(x)]^{w',g'} = 1$, where $g'(x_1,\ldots,x_n) = \langle d_1,\ldots,d_n\rangle$ and $g'(x_n) = g(x_n)$.

4. Quantificational will

$[WILL(P_{n-1}(x))]^{w,g} = 1$ iff for all n-tuples of individuals $\langle d_1,\ldots,d_n\rangle$ accessible at some w' $[P_{n-1}(x)]^{w',g'} = 1$, where $g'(x_1,\ldots,x_n) = \langle d_1,\ldots,d_n\rangle$.

Footnotes

1. I'm indebted to Kratzer (p.c., 1978, 1981) for my understanding of modal relations. Simply for readability, I leave off reference to the ordering on accessible worlds.

2. Fred Landman (p.c.) pointed out to me that we have to make some distinction between what is determined by law and what is required by law to make this really work. Imagine there is an individual who, by Massachusetts law, is required to be a citizen but who is breaking the law and is not a citizen. We want it to be false that this person may conduct arrests under Massachusetts law. We want the truth conditions for 42 to require that if x is a citizen in a world w' where what is determined by Massachussetts laws holds, then there is a world w'' where what is required by Massachussets law holds s.t. x conducts arrests is true at w''. It will be determined by law, for example, that children born in Massachussetts are citizens of Massachussetts and that people who are citizens have social security numbers; it will be required by law, for example, that no one commit a murder and that all citizens pay state taxes. Assuming that what is determined by law is also required by law, then the determined-by-law worlds will be a subset of the required-by-law worlds, and this will give us a way of stating how the stacked accessibility relations in 42 are related to one another.

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